tro-mechanical devices **420** and **430** may be operating at frequencies f_2 and f_3, respectively, where f_2 and f_3 are resonant modes of each of the electro-mechanical devices **420** and **430**. In this operational mode, the electro-mechanical transducer **400** can produce an output having only two peaks, as illustrated, for example, in FIG. **7** as **520** and **530**. This operational mode can have two frequencies that are different from the two frequencies for first operational mode described above. Additionally, the third operational mode can have two frequencies that are different from the two frequencies of the second operational mode. Therefore, by changing the operational mode of the electro-mechanical transducer **400**, the resultant frequencies of the haptic feedback can be changed.

[0047] In other operational modes, the electro-mechanical transducer **400** can be operated such that one of electro-mechanical devices **410**, **420** and **430** is operating at frequencies f_1, f_2 and f_3, respectively, where f_1, f_2 and f_3 are resonant modes of each of the electro-mechanical devices **410**, **420** and **430**. In these operational modes, the electro-mechanical transducer **400** can produce an output having only one peak at a time. In other words, operational modes are possible where only a single electro-mechanical device is actuated at a given time.

[0048] The voltage can be modulated at a number of different drive frequencies, f_d. For example, the drive frequency f_d can approximate a resonant mode of the electro-mechanical devices. Alternatively, f_d can include any other frequency that is an integral multiple of the electro-mechanical device's resonant frequency.

[0049] While certain operational modes have been described with reference to FIG. **5**, it will be apparent from this discussion that many other operational modes are possible. For example, by providing additional electro-mechanical devices, the number of possible operational modes increases. Additionally, while only three piezoelectric bars were illustrated in FIG. **5**, any number of piezoelectric bars may be employed.

[0050] Additionally, while the embodiments were described above with reference to electro-mechanical devices that included piezoelectric bars, any electro-active material or device can be used. For example, the electro-mechanical devices can include electro-active polymers (EAP), voice coil transducers or other electromagnetic device, an inertial resonant device, or a resonant eccentric rotating mass (HERM) device. An example of an inertial resonant device is described in U.S. Pat. No. 6,088,019. An example of a HERM device is described in U.S. Pat. No. 7,161,580.

[0051] FIG. **8** illustrates an alternative embodiment of an electro-mechanical transducer **600** having multiple masses **620**, **630**, and **640** disposed on the same piezoelectric bar **610**.

[0052] In this embodiment, electro-mechanical transducer **600** comprises one electro-mechanical device, the structure of which corresponds to the structure of electro-mechanical transducer **600**. The piezoelectric bar **610** is secured to a base member **650**, which acts as a mechanical ground and remains substantially fixed with respect to the movement of the electro-mechanical device **600**. Masses **620**, **630**, and **640** can have equal weights or can have different weights. Alternatively, the weights of the two masses can be equal to one another, while the weight of the third mass can be different. Additionally, the masses **620**, **630**, and **640** can be equally spaced along the length of the piezoelectric bar **610** or can be spaced at any desired location along the length of the piezoelectric bar **610**. The weight of and spacing between masses **620**, **630**, and **640** allow the electro-mechanical device to be designed to have a predetermined number of resonant frequencies.

[0053] Next, the operation of the embodiment illustrated in FIG. **8** will be described with reference to FIGS. **6-10**. FIGS. **7-10** illustrate an example of the different operational modes that can be obtained with an electro-mechanical transducer **600** bearing three masses. The bends in the piezoelectric bar **610** are exaggerated in this figure to illustrate the bending of the piezoelectric bar **610** more clearly.

[0054] Frequency modulated voltage can be applied to the piezoelectric bar **610**. As illustrated in FIG. **9**, the electro-mechanical device is initially in a resting position. FIG. **10** illustrates a first resonant mode of the electro-mechanical device. FIG. **11** illustrates a second resonant mode of the electro-mechanical device. FIG. **12** illustrates a third resonant mode of the electro-mechanical device. The modes illustrated in FIGS. **7-10** will produce a resultant output having frequencies that are similar to the frequencies illustrated in FIG. **7** due to the superposition of the three resonant modes produced by the electro-mechanical device.

[0055] FIG. **13** illustrates a method for producing an operational mode of an electro-mechanical transducer, according to an embodiment. At step **1110**, a haptic feedback signal is generated. At step **1120**, the haptic feedback signal is supplied to a driver. At step **1130**, the drive signal is then applied to a first electro-mechanical device. At step **1140**, a drive signal is also applied to the second electro-mechanical device. At step **1150**, the electro-mechanical devices output haptic feedback that includes haptic feedback at a first resonant mode (step **1151**) and haptic feedback at a second resonant mode (step **1152**). The output of haptic feedback at a first resonant mode by a first electro-mechanical device and/or at a second resonant mode by a second electro-mechanical device correspond to an operational mode of the electro-mechanical transducer having the first electro-mechanical device and/or the second electro-mechanical device, respectively.

[0056] Additional electro-mechanical devices can be added and can have the drive signal selectively applied thereto to collectively yield a variety of different operational modes of the electro-mechanical transducer. Alternatively, the electro-mechanical transducer may include multiple masses, as illustrated in FIG. **8**. By altering the frequency of the drive signal such that it substantially corresponds to the resonant frequencies of the electro-mechanical device, the electro-mechanical transducer can output haptic feedback having multiple frequencies for a given operational mode.

[0057] In another embodiment, a number of electro-mechanical devices in a serial configuration, as illustrated in FIG. **8**, can be arranged in parallel as illustrated in FIG. **5**.

[0058] The devices described above are capable of being used in small, portable devices where energy consumption needs to be low. For example, electro-mechanical transducers can be used in cellular phones, electronic pagers, laptop touch pads, a cordless mouse or other computer peripherals whether cordless or otherwise, a personal digital assistant (PDA), along with a variety of other portable and non-portable devices.

[0059] While the particular embodiments were described above with respect to piezoelectric bars, they are not limited to the use of piezoelectric bars and piezoelectric devices having various structures can be used depending on the desired application of the electro-mechanical transducer. For example, the piezoelectric device can have a planar shape where the width is approximately the same as the length.

[0060] While particular embodiments have been described with reference to piezoelectric ceramics, numerous other electro-mechanical devices may be used. For example, the electro-mechanical devices may include electro-active poly-